

A new long-spined dinosaur from Patagonia sheds light on sauropod defense system

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Supplementary Information

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1. Characters and Taxa

The character list include in this analysis is the same of Xu et al.,¹, as well as the taxa include with the addition of *Amargatitanis macni*^{2,3}, *Pilmatureia faundezi*⁴ and *Bajadasaurus pronuspinax*.

2. Phylogenetic assumption

The following characters were treated as ordered (actual character number): 12, 58, 95, 96, 102, 106, 108, 115, 116, 119, 120; 145, 152, 163, 213, 216, 232, 233, 234, 235, 252, 256, 298, 299, and 301.

3. Phylogenetic results

The analysis retrieved 820 most parsimonious trees of length 1114 steps. The strict consensus shows a great politomy at the base of Neosauropoda. In order to recognize unstable taxa we compared pruned trees, and resulted number of nodes gained, using the Pruned Tree command in TNT. *Erketu ellisoni* was recovered in multiple positions such as a diplodocid, a basal macronarian, a basal titanosauriform, and both basal and derived titanosaurian. *Amargatitanis macni* was recovered in different position within Flagellicaudata (Supplementary Fig. 12). As a consequence, a reduced strict consensus tree was generated via a posteriori deletion of both unstable taxa.

**4. Synapomorphies supporting *Bajadasaurus* within Diplodocoidea,
Flagellicaudata, Dicraeosauridae and *Lingwulong*+more derived Dicraeosauridae
(actual character number)**

Diplodocoidea

Char. 145 1→2
Char. 163 1→0
Char. 184 0→1
Char. 205 0→1
Char. 215 0→1

Flagellicaudata

Char. 8 0→1
Char. 12 1→2
Char. 53 1→0
Char. 82 0→1
Char. 86 0→1
Char. 132 0→1
Char. 158 0→1
Char. 193 0→1
Char. 198 0→1
Char. 216 1→2
Char. 286 0→1
Char. 295 1→0
Char. 327 0→1
Char. 370 0→1

Dicraeosauridae

Char. 4 0→1
Char. 26 0→1
Char. 34 1→0
Char. 50 0→1
Char. 85 0→1
Char. 371 0→1

Lingwulong+more derived Dicraeosauridae

Char. 35 0→1

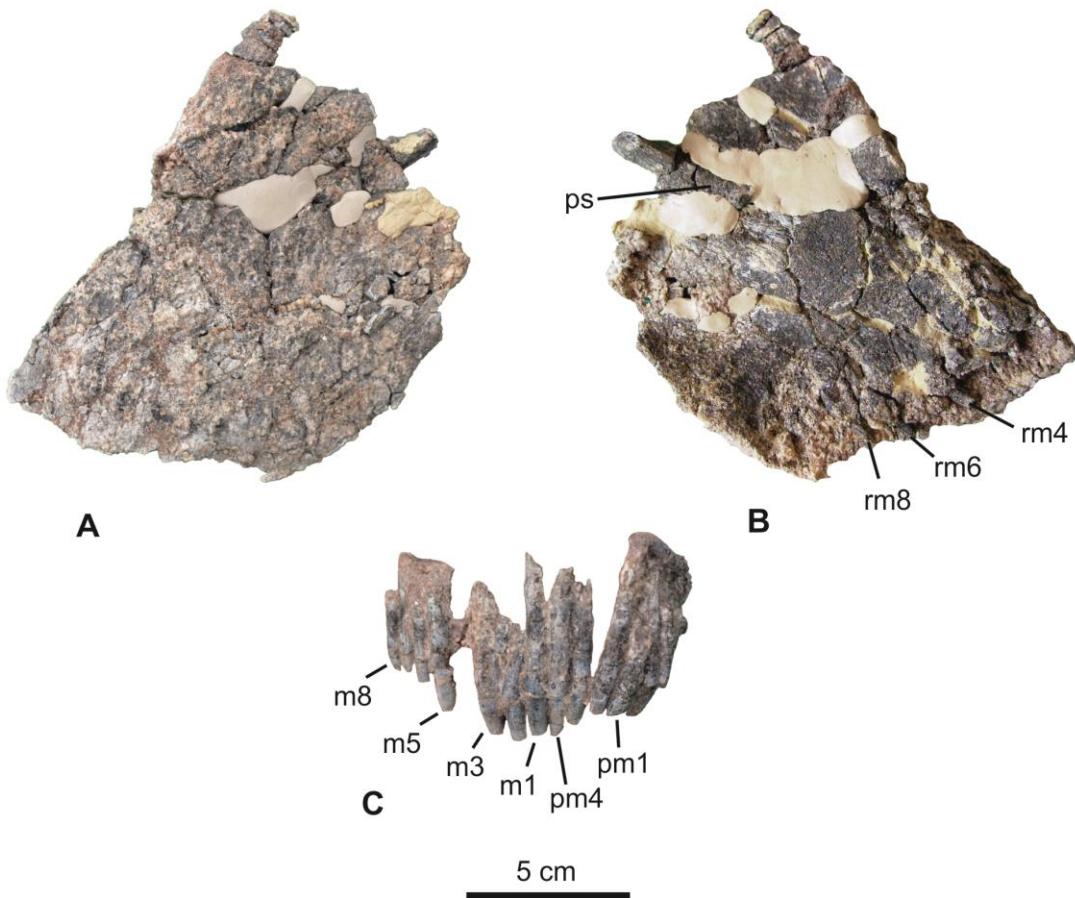
Char. 113 1→0

Char. 135 1→0

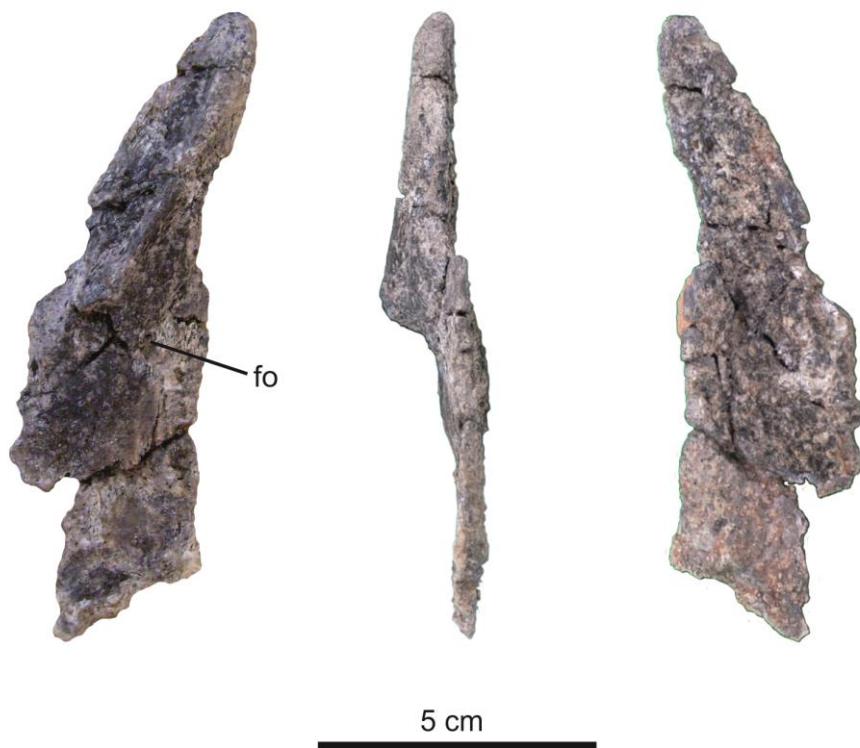
Char. 139 1→0

Char. 374 0→1

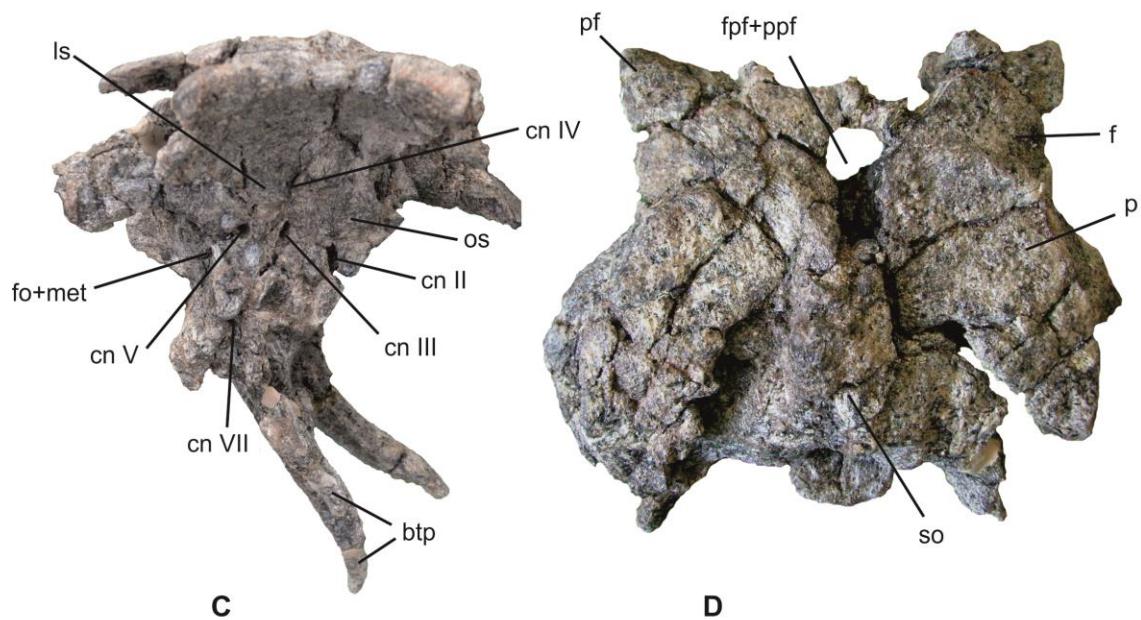
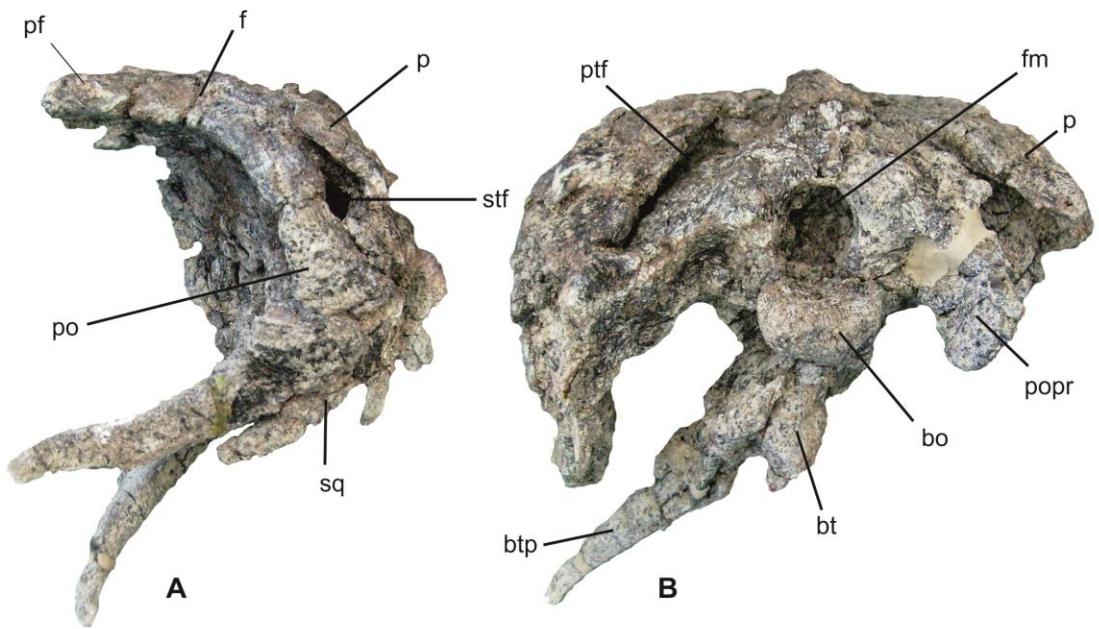
5. Supplementary Figures



Supplementary Figure 1. Left Maxilla and upper teeth of *Bajadasaurus pronuspinax* gen. et sp. nov. (MMCh-PV 75). Maxilla in lateral (A) and medial (B) views. Associated upper teeth in lateral (C) view. m, maxillary tooth; pm, premaxillary tooth; ps, palatal shelf; rm, replacement maxillary tooth.

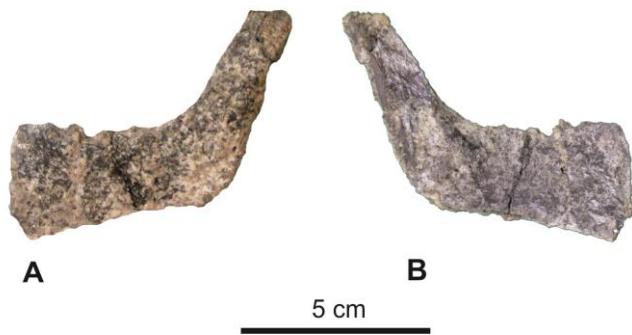


Supplementary Figure 2. Lacrimal of *Bajadasaurus pronuspinax* gen. et sp. nov. (MMCh-PV 75). Anterior (A) and medial (B) views. fo, foramen.

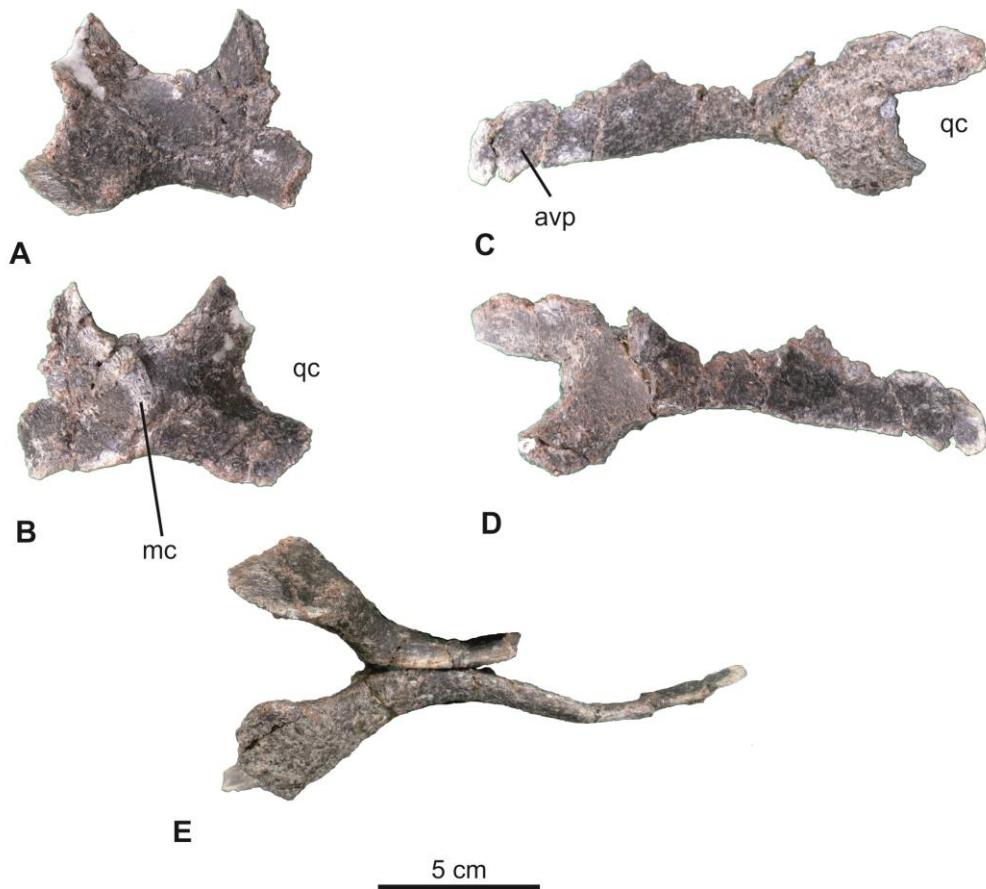


10 cm

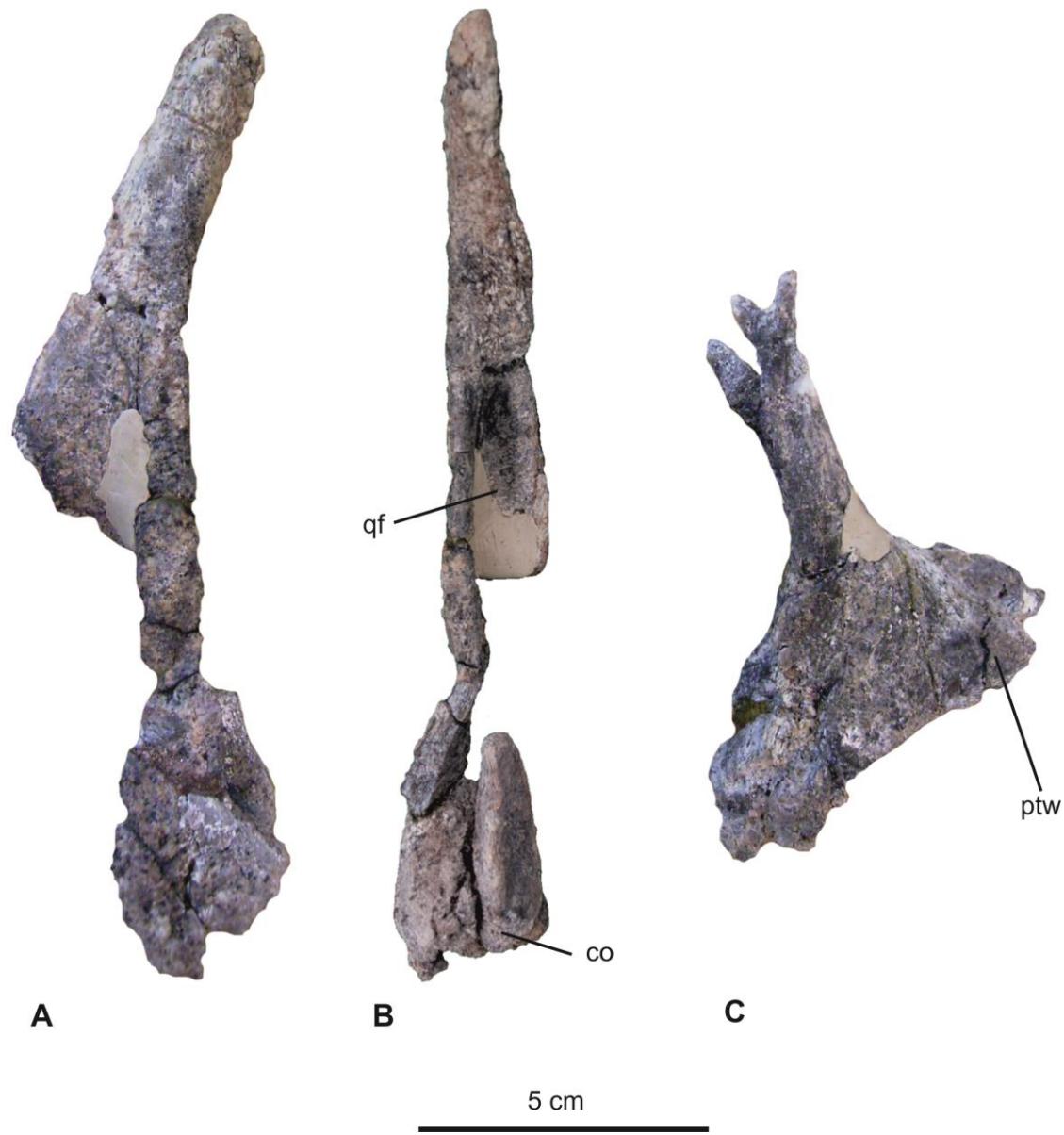
Supplementary Figure 3. Skull roof and braincase of *Bajadasaurus pronuspinax* gen. et sp. nov. (MMCh-PV 75). Left lateral (A), posterior (B), right lateral (C), and dorsal (D) views. Abbreviations as in Figure 2.



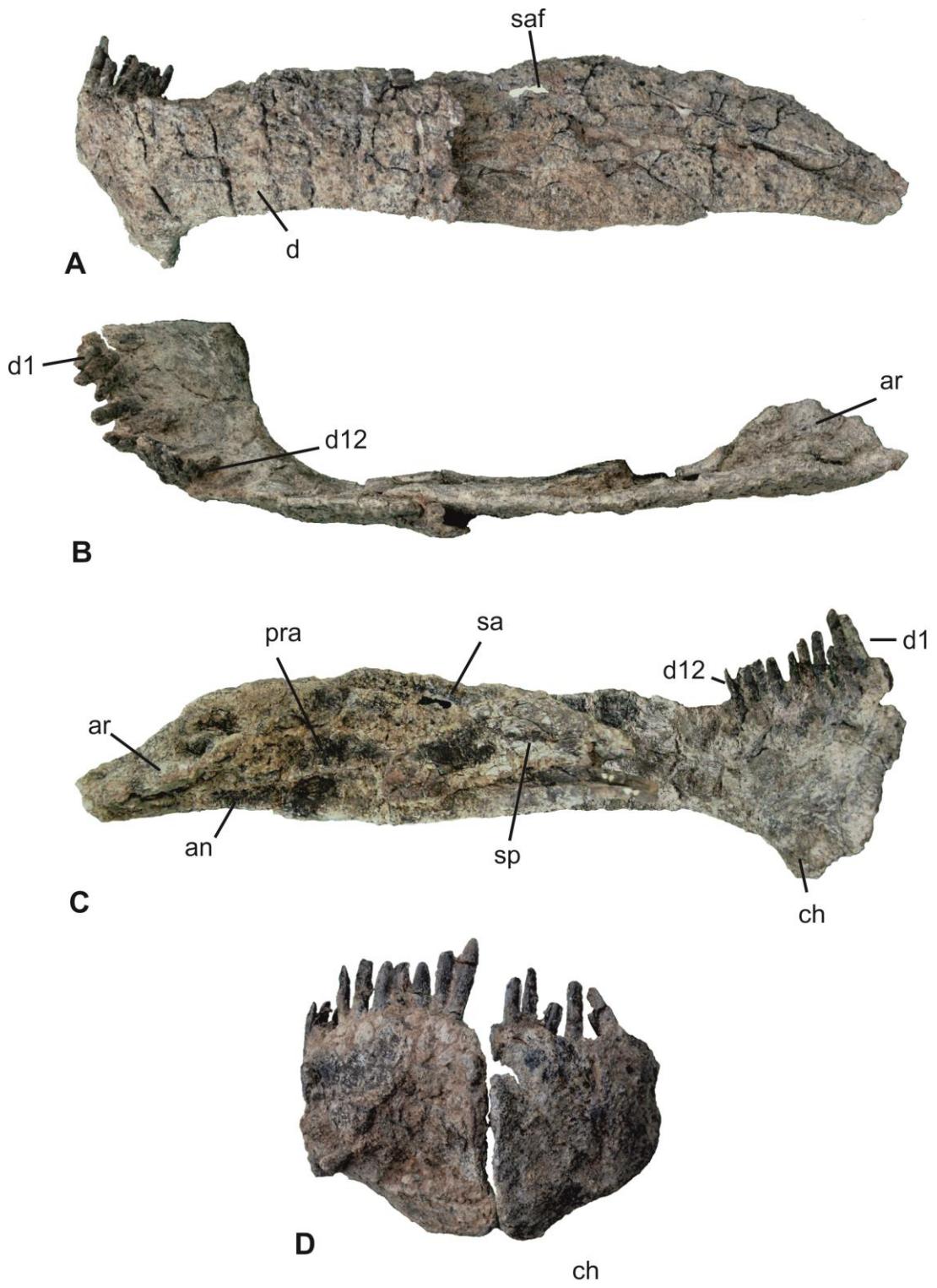
Supplementary Figure 4. Quadratojugal of *Bajadasaurus pronuspinax* gen. et sp. nov. (MMCh-PV 75). Lateral (A) and medial (B) views.



Supplementary Figure 5. Pterygoids of *Bajadasaurus pronuspinax* gen. et sp. nov. (MMCh-PV 75). Right pterygoid in lateral (A) and medial (B) views. Left pterygoid in lateral (C) and medial (D) views. Both pterygoids in ventral (E) view (anterior towards right). avp, anteroventral process; mc, medial crest; qc, contact for the quadrate.

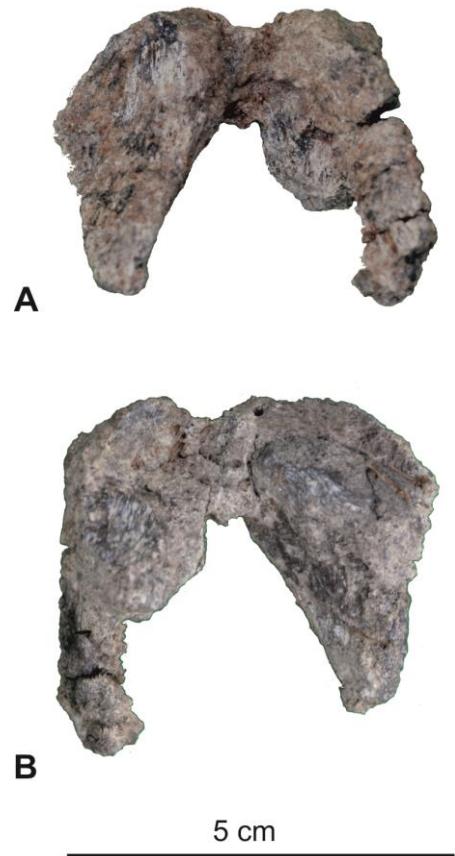


Supplementary Figure 6. Quadrates of *Bajadasaurus pronuspinax* gen. et sp. nov. (MMCh-PV 75). Right quadrate in medial (A) and posterior (B) views. Left quadrate in medial (C) view. co, condyle; ptw, pterygoid wing; qf, quadrate fossa.

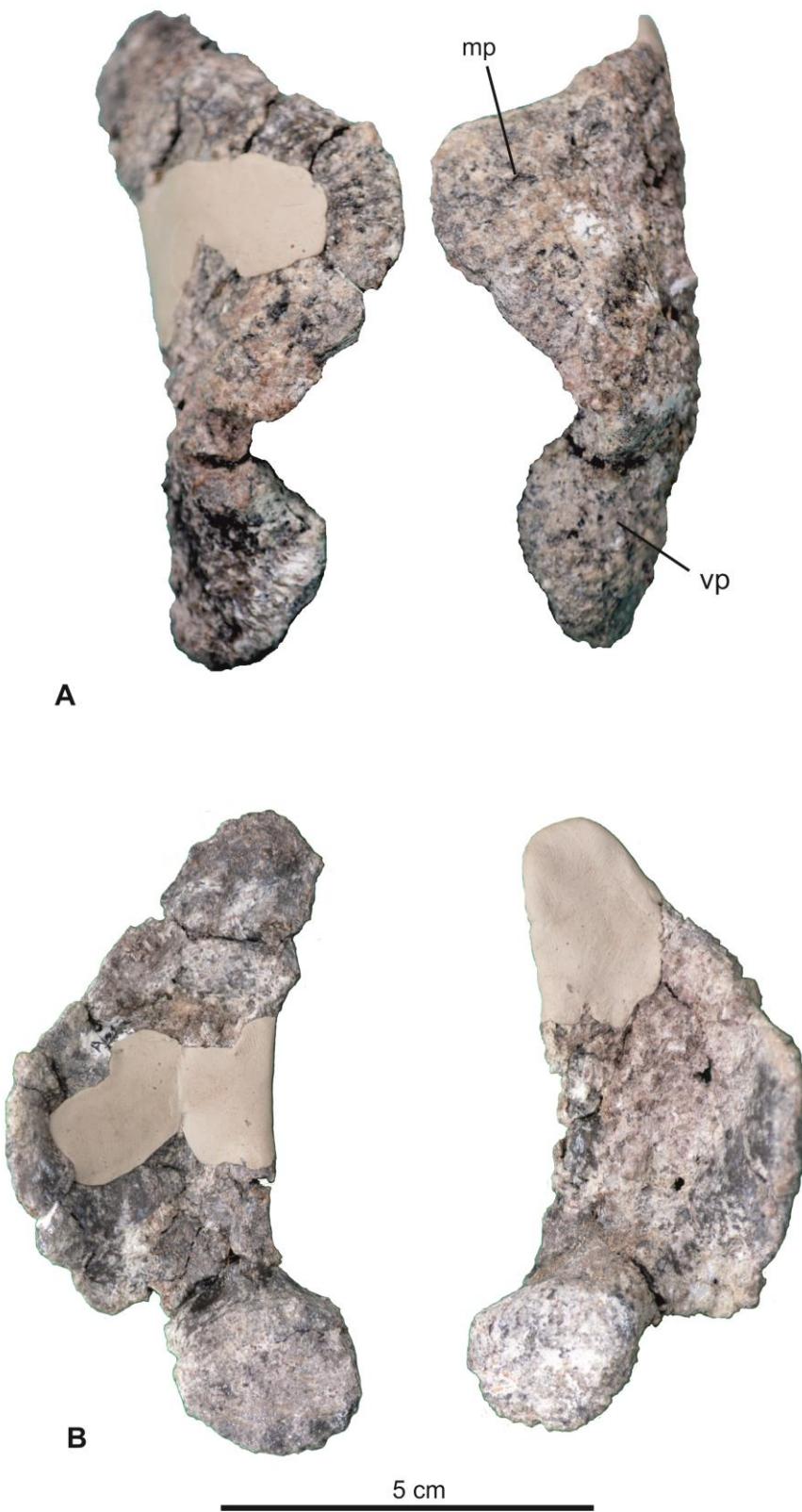


5 cm

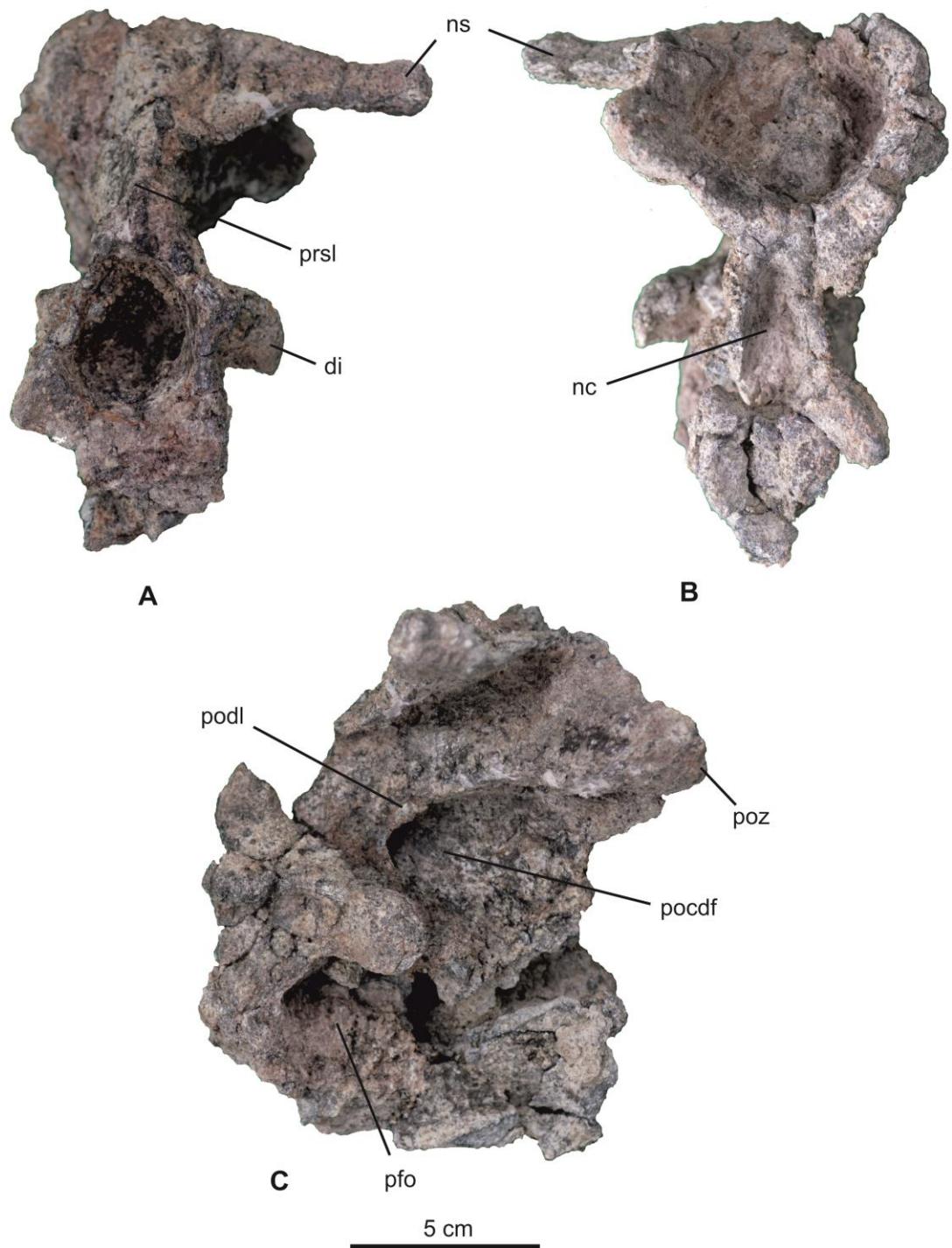
Supplementary Figure 7. Lower jaw of *Bajadasaurus pronuspinax* gen. et sp. nov. (MMCh-PV 75). Left lower jaw in lateral (A), dorsal (B), and medial (B) views. Both dentaries' in anterior (D) view. Abbreviations as in Figure 2.



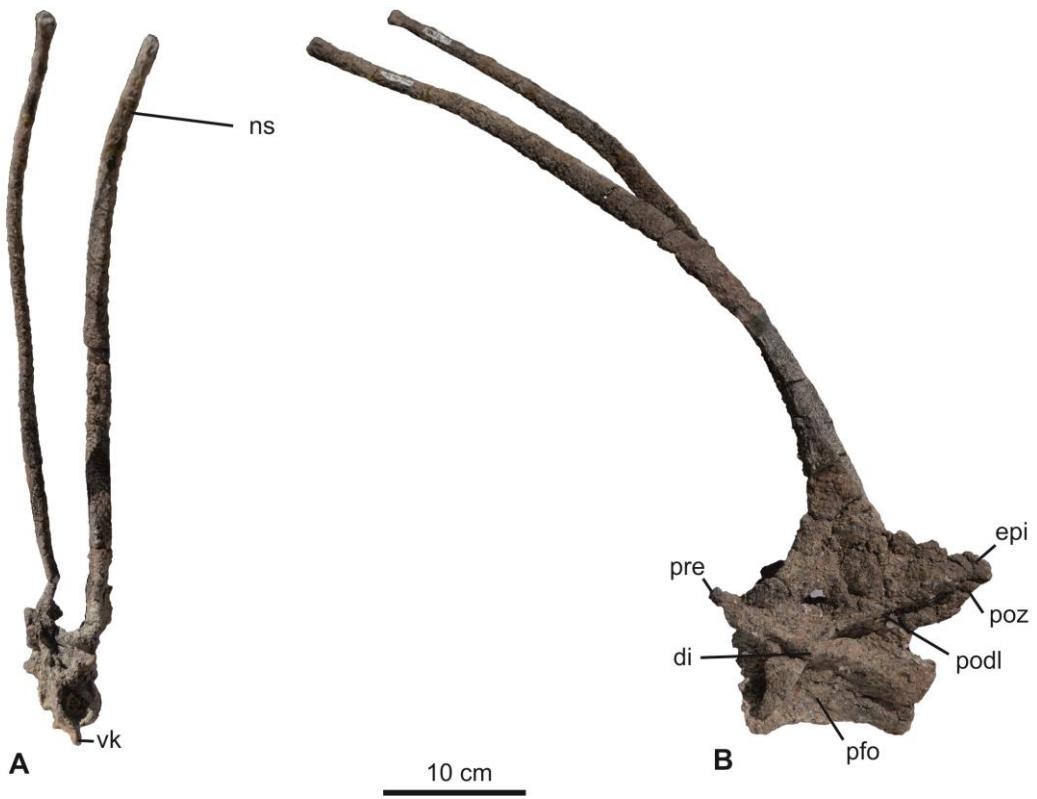
Supplementary Figure 8. Proatlas of *Bajadasaurus pronuspinax* gen. et sp. nov. (MMCh-PV 75). Dorsal (A) and ventral (B) views.



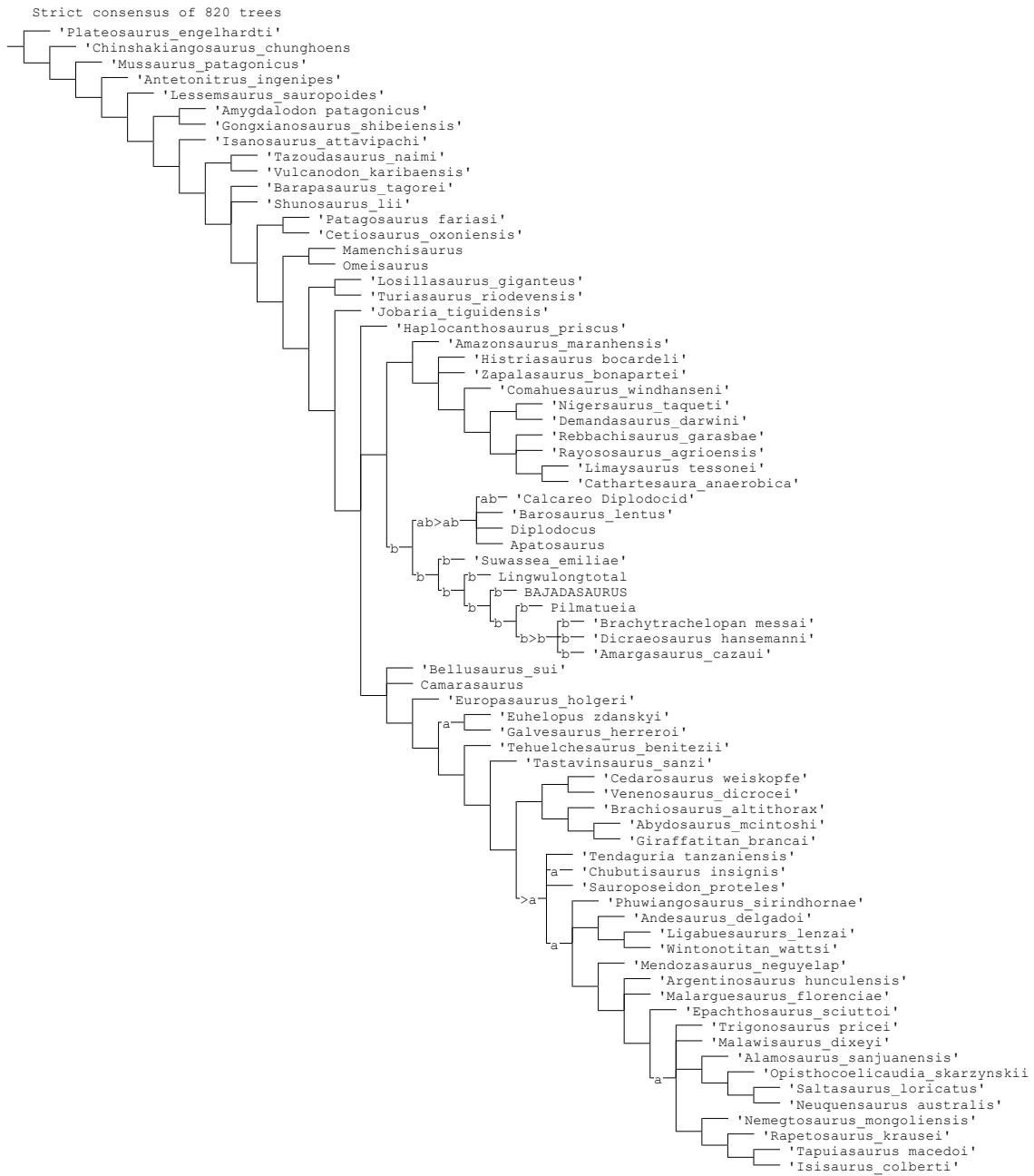
Supplementary Figure 9. Atlantal neurapophyses of *Bajadasaurus pronuspinax* gen. et sp. nov. (MMCh-PV 75). Anterior (A) and medial (B) views. Abbreviations in Figure 2.



Supplementary Figure 10. Axis of *Bajadasaurus pronuspinax* gen. et sp. nov. (MMCh-PV 75). Anterior (A), posterior (B), and lateral (C) views. Abbreviations as in Figure 2.



Supplementary Figure 11. ?Fifth cervical vertebra of *Bajadasaurus pronuspinax* gen. et sp. nov. (MMCh-PV 75). Posterior (A) and lateral (B) views. Abbreviations as in Figure 2.



Supplementary Figure 12. Reduced strict consensus tree showing the unstable positions of *Erketu ellisoni* (a) and *Amargatitanis macni* (b).

6. Skull and vertebral bones measurements of *Bajadasaurus pronuspinax* gen. et sp. nov. (MMCh-PV 75) (in mm, > indicates estimated measurement)

Element	side	apL	tbL	dvH	minW	maxW	lmL	hrdvH	vrapW	aaW	aaH	paW	paH	apnaL	naW	naH	sH
Maxilla	L	132	63	>127	2	18											
Prefrontal	L	57					62										
	R	53					63										
Frontal	L	>79					76										
	R	87					55										
Postorbital	L	60		128	12	34		26	26								
	R	64		124	11	28		28	24								
Quadratojugal	L	>60		>52	2	10		24	14								
Lacrimal	L	30		113	2	14											
Quadrata	L	53				25											
	R			163		25											
Squamosal	L	63		>92		23											
	R	>53		134		22											
Parietal	L	33				47											
	R	31				46											
Supraoccipital				34													
Paroccipital process (exoccipital-opisthotic)	L			27			74										
	R			28			>51										
Occipital condyle					16	32											
Foramen magnum					28	19											
Basal tubera	L			36	14												
	R			36	16												
Basipterygoid process	L			110													
	R			>74													
Pterygoid	L	153		49		50											
	R	>88		46		62											
Dentary	L	144		73		69											
	R	113		73		63											
Surangular	L	208		27													
Angular	L	205		29													
Proatlas	L	32		36	15												
	R	28		32	18												
Atlantal neurapophysis	L	>66		49													
	R	83		63													
Axis		93							46	49	45	40	107	78	75	66	
5th? cervical vertebrae		126							—	67	47	63	210	72	59	61	

Abbreviations

aaH: anterior articular surface height; **aaW:** anterior articular surface width; **apL:** anteroposterior length; **apnaL:** anteroposterior length of neural arch; **dvH:** Dorsoventral height; **hrdvH:** horizontal ramus dorsoventral height; **lmL:** lateromedial length; **maxW:** maximum transverse width; **minW:** minimum transverse width; **naH:** neural arch height; **naW:** neural arch width; **paH:** posterior articular surface height; **paW:** posterior articular surface width; **sH:** spine height; **tbL:** length tooth-bearing portion; **vL:** length ventral edge; **vrapW:** ventral ramus anteroposterior width.

Measurements protocols

Maxilla

apL: measured with the maxilla oriented as in figure 4

dvH: measured with the maxilla oriented as in figure 4

Postorbital

apL: corresponds to the length of the dorsal horizontal ramus

dvH: corresponds to the length of the ventral ramus

hrdvH: measured at mid length

vrapW: measured at mid length

Quadrato

apL: measured at the level of the pterygoid wing

Basal tubera

dvH: measured from the ventral edge of the occipital condyle

Basipterygoid process

dvH: measured from the ventral edge of the basal tubera

Dentary

dvH: measured at symphysis

lmL: measured along the anterior, toothed, sector of dentary

Proatlas

apL: measured at the base

Cervical vertebrae

apL: anteroposterior length of centrum

naH: measured from the neurocentral suture to the base of the neural spine

naW: measured between postzygapophyses

7. Supplementary References

1. Xu, X., Upchurch, P., Mannion, P. D., Barrett, P. M., Regaldo-Fernandez, O. M., Mo, J., Ma, J. & Liu, H. A new Middle Jurassic diplodocoid suggests an earlier dispersal and diversification of sauropod dinosaurs *Nat. Comm.* **9**, 2700 (2018)
2. Apesteguía, S. The sauropod diversity of the La Amarga Formation (Barremian), Neuquén (Argentina). *Gondwana Res.* **12**, 533–546 (2007).
3. Gallina, P. A. Reappraisal of the Early Cretaceous sauropod dinosaur *Amargasaurus macnii* (Apesteguía, 2007), from northwestern Patagonia, Argentina. *Cretaceous Res.* **64**, 79–87 (2016).
4. Coria, R. A., Windholz, G. J., Ortega, F. & Currie, P. J. A new dicraeosaurid sauropod from the Lower Cretaceous (Mulichinco Formation, Valanginian, Neuquén Basin) of Argentina. *Cret. Res.* **93**, 33–48 (2019).